



PERGAMON

Renewable Energy 16 (1999) 1049–1052

**RENEWABLE
ENERGY**

ELECTRICITY PRODUCTION IN RURAL VILLAGES WITH A BIOMASS STIRLING ENGINE

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ABSTRACT

The goals of the project were the design, construction and operation of a Stirling engine, which is heated by the flue gas of a biomass furnace. The α -type Stirling engine was selected for cost reasons, because many parts from industrial mass production can be used. The necessary maintenance and repair work of the Stirling engine can be done by a standard car work shop. The major problem of this development is given by the dust content of the flue gas. To avoid obstacles and fouling at the outside of the heat exchanger smooth heat resistant tubes have to be used. All kinds of biomass, e.g. agricultural waste, log or chiped wood, shells of fruits like coffee, may be used as fuel. A biomass Stirling engine with air (nitrogen) as working gas and a shaft power of 3 kW was designed and constructed for lab tests. With a working gas pressure of 33 bar, 600 rpm, a shaft power of 3,2 kW at a coefficient of performance of 25% (shaft power/heat) was verified. Engine durability tests, performance measurements and improvements were finished in 1997. In the next step of the development the shaft power will be enlarged to 30 kW. © 1998 Elsevier Science Ltd. All rights reserved.

KEYWORDS

Rural village, electricity production, biomass, Stirling engine, flue gas powered,

1. INTRODUCTION

Decentralized small scale electricity production in countries without well developed electric grids is of high interest. If biomass or agricultural waste is available as fuel many applications can be expected at small companies and communities. Applications in the following areas may be expected:

- Rice industry in China, India, Thailand, Bangladesh, Burma, Nepal, Sri Lanka
- Palm oil industry in Indonesia
- Citriculture in Belize
- Sugar industry in India, China, Mexico
- Coffee industry in Columbia
- Wood industry in Brasilia, Honduras
- Communities without electrical grid connection

Large quantities of rice straw, rice shells and of other agricultural waste were discovered /1/.

2. THE BEST TECHNICAL OPTION

After basic considerations and evaluation of several technical processes it was found that a biomass fired Stirling engine should be the best technical and economical solution for a small scale grid independent power production in the power range of 5 to 100 kWel /2/. Based on these above considerations, the decision was taken in favor of an α -type Stirling engine whose heater is equipped with **smooth heat exchanger pipes** for which **no hot flue gas**



Fig. 1: Test biomass Stirling engine at JOANNEUM RESEARCH, Graz, 3 kW

cleaning is necessary. The decision to use air or nitrogen as working gas was based on the following considerations:

- Cleaned, oil-free air can be supplied even in rural villages by an adapted compressor.
- Air is a cheaper working gas than helium and everywhere available.
- Seals against air loss can be obtained at lower costs than those against helium loss, and in many cases standard products can be used /3/.

- The higher weight of Stirling engines operating with air (nitrogen) as working gas is of little significance in stationary applications.
- The coefficient of performance generally does not depend on the working gas.

The crank mechanism used in the Stirling engine was that of a series produced engine for a motor cycle. Figure 1 shows this biomass test Stirling engine. The relatively large dead space of the heat exchangers requires, therefore, that the active working space of the entire Stirling engine be adapted accordingly.

3. TECHNICAL PERFORMANCE DATA MEASURED

The tests with the experimental Stirling engine were performed on a testbed configuration with a wood chip furnace. Results were found as showed in Table I:

Table I: Test results with a 3 kW biomass Stirling engine in 1996 /2/

Flue gas temp.	1.000	°C	Mean preasure	33 (40)	bar
Dust content	70 ... 700	mg/m ³ N	Bore/stroke	140/51	mm
Engine cooler	30 ... 70	°C	Swept piston volume	840	cm ³
Cylinder cooler	20 ... 30	°C	Compensator	17	liter
Rod seals cooler	20 ... 30	°C	Working speed	600	RPM
Thermal input	12,5	kW	Idling speed	950	RPM
Engine cooler	8,75	kW	Efficiency (COP)	0,25 ... 0,28	-
Cylinder coolers	0,52	kW	Crankmechanism	DUCATI 500 cm ³	
Rod seals cooler	0,03	kW	Flyweel/starter	Austrian Truck	
Shaft power max.	3,2	kW	Working gas	air, nitrogen	

4. PROCESS CONFIGURATION IN PRICIPLE

Figure 2a shows the configuration of the biomass Stirling engine unit in principle which includes a heat exchanger to preheat the combustion air by heat recovery from the flue gas. This measure makes sense if the relationship between electricity produced (ELP) and the biomass fed (BFin) should be enlarged. The sankey diagram in Figure 2b indicates further that this relationship reaches 0,20. The COP expected for this application will be 0,33. The sankey diagram shows the relationship between the electricity produced and the thermal capacity of the combustor. It is easy to see that the combustor has to have about 50 kW_{th} if an electric power of 10 kW_e should be generated. The heat rejected by the engine cooler at temperatures of 60/40 °C will reach about 25 kW_{th} at full load.

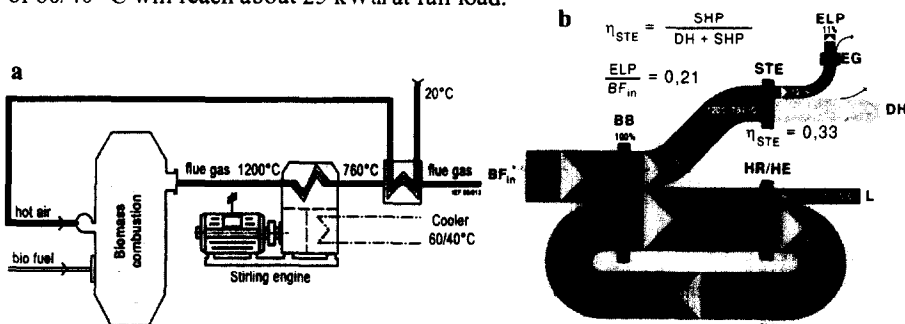


Figure 2: Biomass Stirling engine (a) for grid independent electricity production and sankey diagram (b). BB ... biomass boiler, BFin ... biofuel input, DH ... engine cooler (40/60 °C), STE ... Stirling engine, ELP ... electric power, HR/HE ... heat recovery -heat exchanger, L ... thermal losses, SHP ... shaft power, η_{STE} ... COP of the Stirling engine,

5. ELECTRICITY PRODUCTION WITH A BIOMASS STIRLING ENGINE

The primary goal of the small scale plant showed in Figure 3 is the grid independent production of electricity from biomass in the capacity range of 5 to 30 kW_{el}. The principle arrangement of the components is indicated in Figure 3. The important parts of the small scale power production unit are the biomass combuster, the Stirling engine as showed in Figure 1, the electric generator, the engine cooler circuit with pump, fan and the water/air heat exchanger. Biomass wastes like coffee shells, rice husks, agricultural residues or any kind of wood may be used as a fuel. Adaptations of the biomass combuster to several biofuels for improvements of the combustion process will be necessary. The heater of the Stirling engine is directly heated by the hot flue gas of the combuster. A heat exchanger with smooth surface at the flue gas side for heat recovery is used to preheat the combustion air to some hundred degree centigrade before entering the combuster. The belt driven blower and the cooling water pump (not visible in Figure 3) of the engine cooler are important components for rejecting the heat.

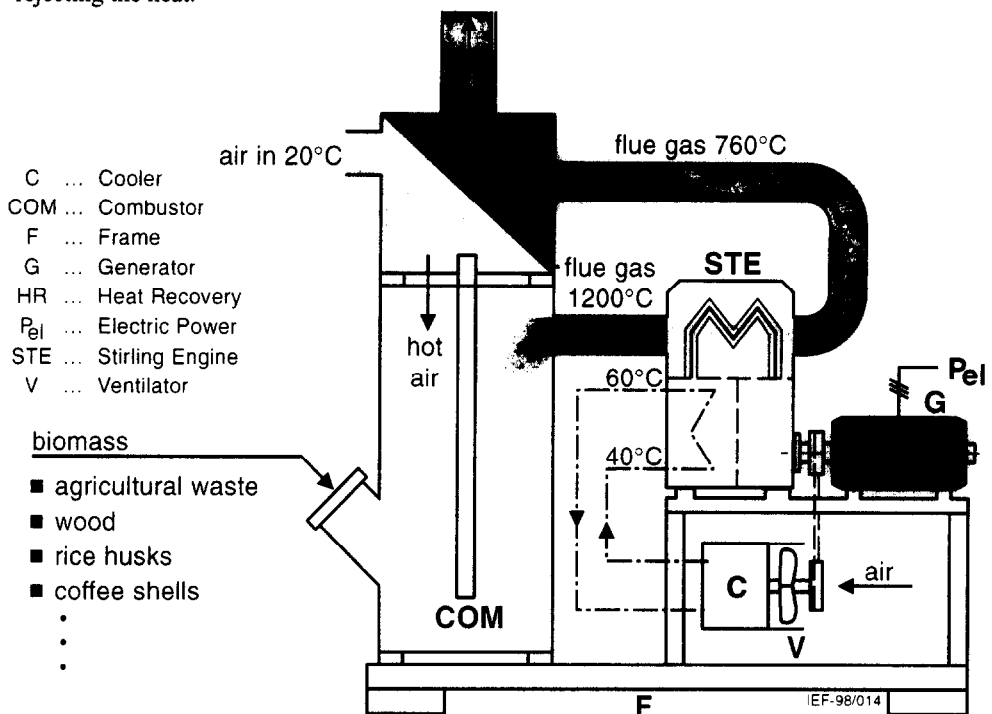


Figure 3: Electricity production from biomass by a Stirling engine

6. REFERENCES

- /1/ Sitte, G.: *Marktuntersuchungen für Stirlingmotoren zur Stromerzeugung mit dem Brennstoff Biomasse*, diploma thesis at the Technical University Graz, 1998
- /2/ Podesser, E.; Dermouz, H.; Padinger, R.; Wenzel, T.: *Entwicklung eines mit Holz betriebenen Stirling-Kleinkraftwerkes zur dezentralen Strom- und Wärmeerzeugung - Phase II*, REPORT IEF-B-12/95, JOANNEUM RESEARCH, Institute for Energy Research, 1995.
- /3/ Hargreaves, C.M.: *The Philips Stirling Engine*, Elsevier-Verlag, 1991.
- /4/ Carlsen H.: 40 kW-Stirling engine for solid fuel; Fachbericht beim Stirling-Forum Osnabrück, 1996.